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ELECTRON ENERGY-LOSS SPECTROSCOPY OF CARBON IN INTERPLANETARY DUST PARTICLES. Lindsay P. Keller¹, John P. Bradley¹, Kathie L. Thomas², and David S. McKay³, ¹MVA, Inc., 5500 Oakbrook Parkway, Norcross, GA 30093, ²C23, Lockheed, NASA/JSC, Houston, TX 77058, and ³SN, NASA/JSC, Houston, TX 77058

Introduction. The nature of the carbon-bearing phases in IDPs provides information regarding the chemical and physical processes involved in the formation and evolution of the early solar system. Several carbon-bearing materials have been observed in IDPs [e.g. 1], but details of their nature, abundance, and distribution are still poorly known. A knowledge of the abundance and nature of carbon in IDPs is useful in constraining the sources of IDPs and for comparisons with other chondritic materials. Estimates of carbon abundance in anhydrous and hydrated IDPs indicate that most of these particles have significantly higher carbon than the carbonaceous chondrites [2,3]. Mineralogical analyses show that carbonates are only a minor component of most hydrated IDPs, and so the high carbon abundances in this group of IDPs indicates that other carbon-bearing phases are present in significant concentrations [3]. Using the technique of electron energy-loss spectroscopy (EELS), we have identified two forms of carbon in a hydrated IDP, oxidized carbon (carbonates) and amorphous elemental carbon.

Methods. EELS spectra were obtained using a JEOL 2010 TEM equipped with a GATAN parallel EELS detector. Carbonate standards were finely ground and dispersed onto SiO thin films for the EELS analysis. Ultramicrotome thin sections (~80 nm thick) of IDPs were placed on holey carbon films and only those regions of the thin sections that were over holes in the film were analyzed. EELS spectra were acquired at 0.2 eV/channel, with an analysis time of 1 second/scan. The scanned spectra were summed until more than 50K photodiode counts in the carbon K-absorption edge were accumulated.

Carbon Near-edge structure. In amorphous carbon, the excitation of a 1s electron to the first empty band (the π^* conduction band) results in the onset of the carbon K-edge at ~284 eV. The broad peak in the EELS spectra at ~292 eV corresponds to transitions from 1s to the σ^* conduction band. In graphite, the π^* peak involves the pz orbitals (the weak bonds between planes of carbon atoms in the graphite structure), while the sigma* peak results from sp² hybrid bonds between coplanar carbon atoms. Structural variations (i.e. the degree of graphitization) can be estimated by comparing the relative proportions of π^* and σ^* bonding in the high-loss region [4,5].

There is a distinct energy shift in the onset of the carbon K-edge in carbonates relative to amorphous carbon. In carbonates, the onset of the carbon K-edge occurs at ~290 eV with a second broader peak centered at ~302 eV [6].

Results and Discussion. EELS spectra were collected from several regions (~0.5 μ m in diameter) in thin sections of L2006G1, a hydrated IDP that contains 20 wt.% C [3]. L2006G1 consists of abundant Mg-rich saponite that coexists with fine-grained Fe-Ni sulfides. Distinct grains of Mg-Fe carbonates are observed in the thin section. This IDP shows no mineralogical evidence of strong heating (e.g. a magnetite rim) even though the diameter of the particle is ~25 μ m.

Typical EELS spectra from L2006G1 are shown in Figure 1. Spectra obtained from the carbonate grains show the characteristic doublet structure for oxidized carbon, however, they also exhibit a slight contribution from indigenous amorphous carbon (the small peak with an onset at 284 eV). EELS spectra from other areas in the thin sections (e.g. phyllosilicate-dominated regions) have carbon K-edges that are typical of amorphous carbon. Comparisons with the edge structure of the carbon support film suggest that the amorphous carbon in L2006G1 is more disordered than the holey carbon film.

Conclusions. The analysis of the carbon near-edge structure in the EELS spectra from a hydrated interplanetary dust particle shows that carbonates and amorphous elemental carbon are the major carbon-bearing phases. The carbonates occur as discrete grains in the IDP whereas the amorphous carbon is associated with the fine-grained phyllosilicates. Electron energy-loss spectroscopy in the TEM provides a means of mapping the chemical state of carbon in IDPs with high spatial resolution

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Figure 1. Electron energy-loss spectra of the main carbon-bearing phases in L2006G1.

